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Title: National Criticality Experiments Research Center: Capabilities and Experiments

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Intended for: University seminar.

National Criticality Experiments Research Center: Capabilities and Experiments

J. Hutchinson, D. Hayes, W. Myers

Los Alamos National Laboratory
NEN-2 (Advanced Nuclear Technology)

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Overview

- DAF Timeline
- Critical Experiments:
  - Planet
  - Comet
  - Flattop
  - Godiva
  - Current status of critical assembly machines
- Nuclear material handling and subcritical experiments:
  - Nuclear material items
  - Radiation detector measurements

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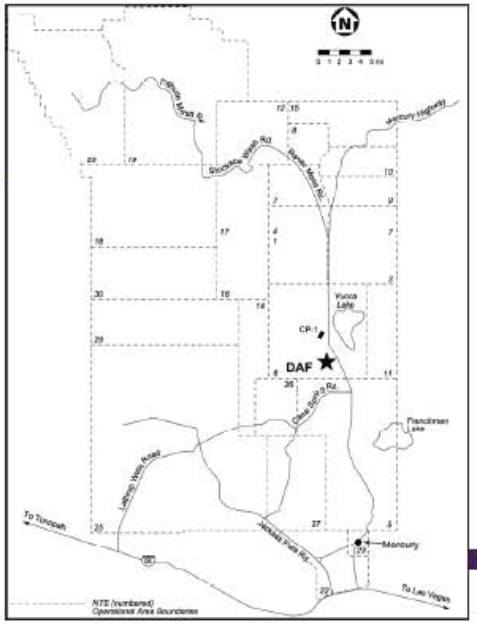
TA-18 Mission Relocation

Relocating National Asset Special Nuclear Material (SNM), and Unique SNM Handling and Experimental Capabilities to the Nevada Test Site

TA-18, Pajarito Site
Los Alamos National Laboratory



Device Assembly Facility (DAF)
Nevada Test Site (NTS)

First shipment from LANL TA-18 to the DAF	*First security category 1 shipment from LANL to the DAF*	*New start of hazard category 2 operations approved*	*Final shipment to reduce TA-18 to below security category 2*
September 2004	December 2004	September 2005	October 2005

NNSA National Nuclear Security Administration

Los Alamos NATIONAL LABORATORY EST. 1943

DAF Timeline

- TA-18 operated at LANL from 1945-2005.
- 2004-2005: Shipment of nuclear material from TA-18 to the DAF.
- 2007: Nuclear material handling resumed at DAF.
- 2011: Critical experiment capability resumed at DAF.

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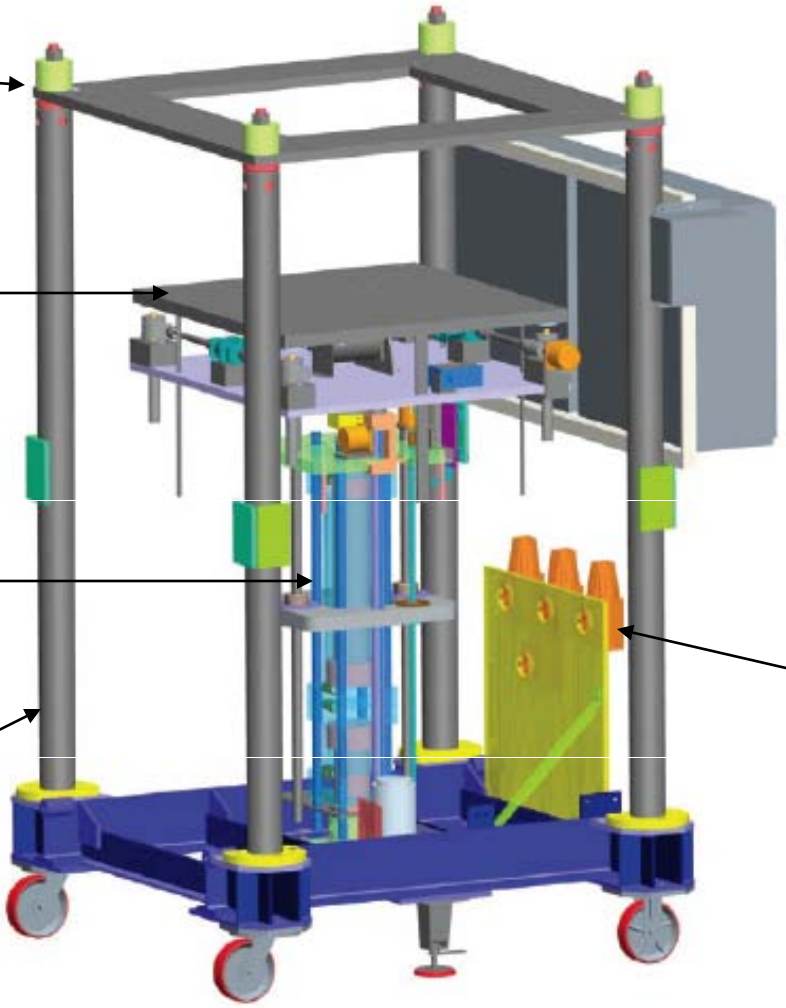
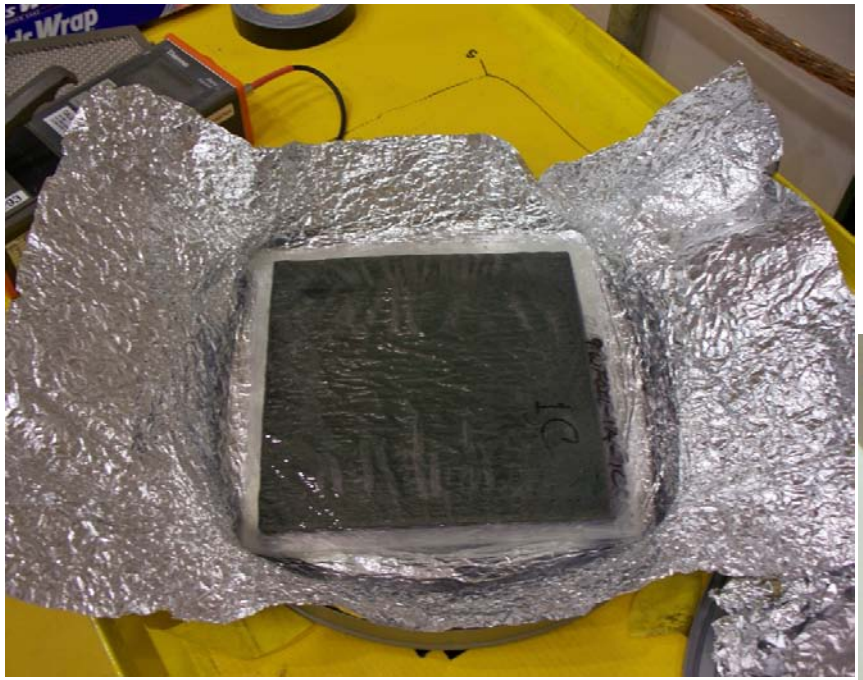
Planet

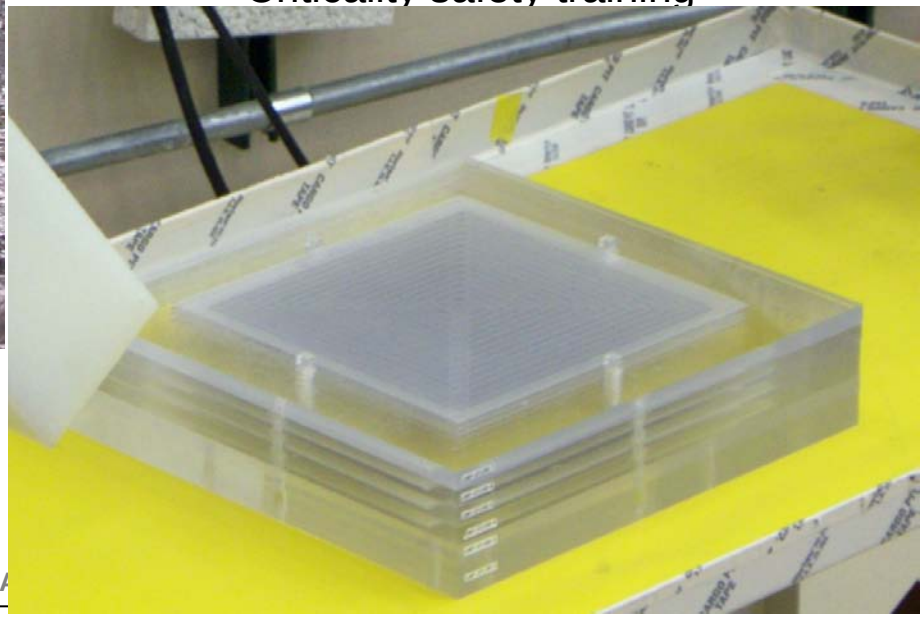

Upper Support Platform
Platen Table Sub-Assembly
Ram Table Sub-Assembly
Hydraulic Valves
Support Structure

Planet

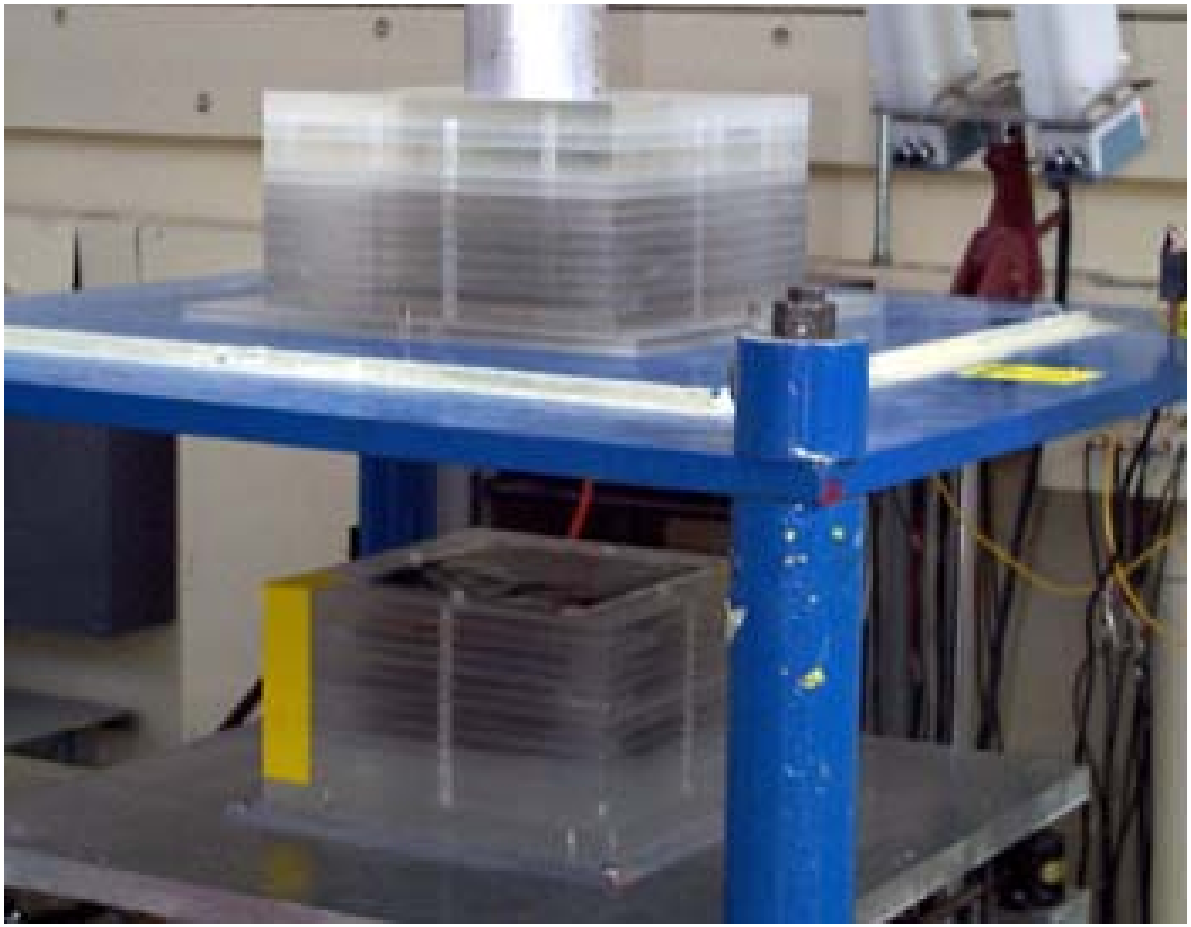
- Class foils experiment



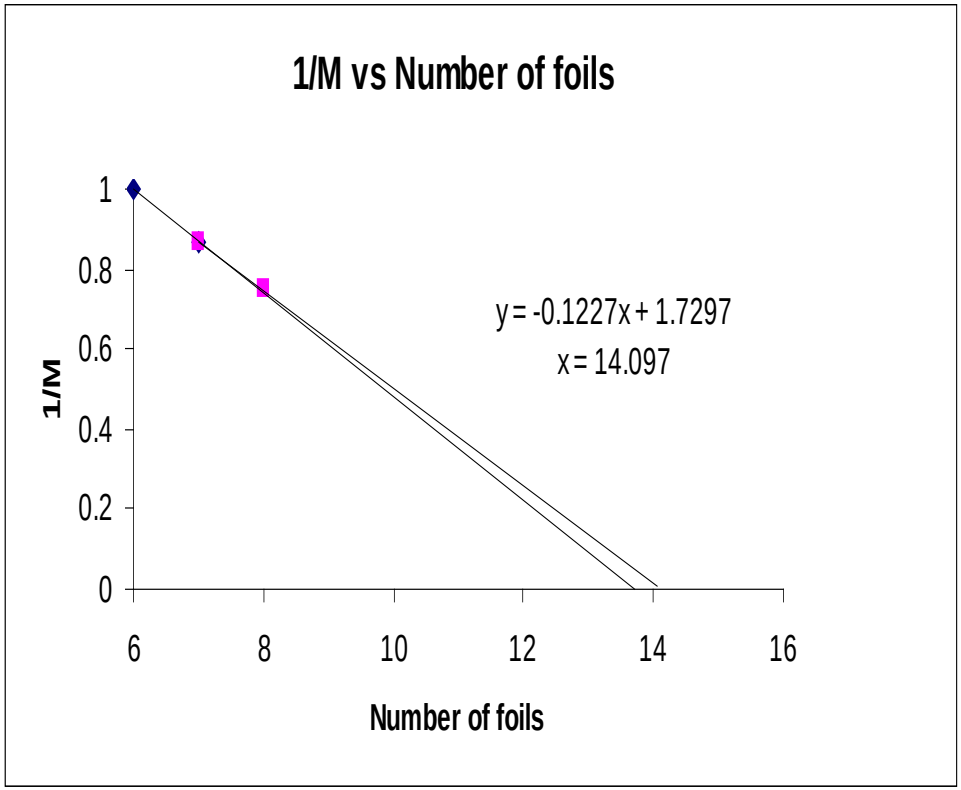
- Recent applications include:.
  - Integral Neutron Cross Section Benchmark studies.
  - Minimum Critical Mass Studies
  - Critical assembly operator training.
  - Criticality safety training



Planet



Planet



Predicted critical is 14 (14.09) foils

For well behaved systems, the predicted critical will increase with each step.

1/2 way is 11 (11.04) foils

3/4 of critical mass is 10 (10.56) foils

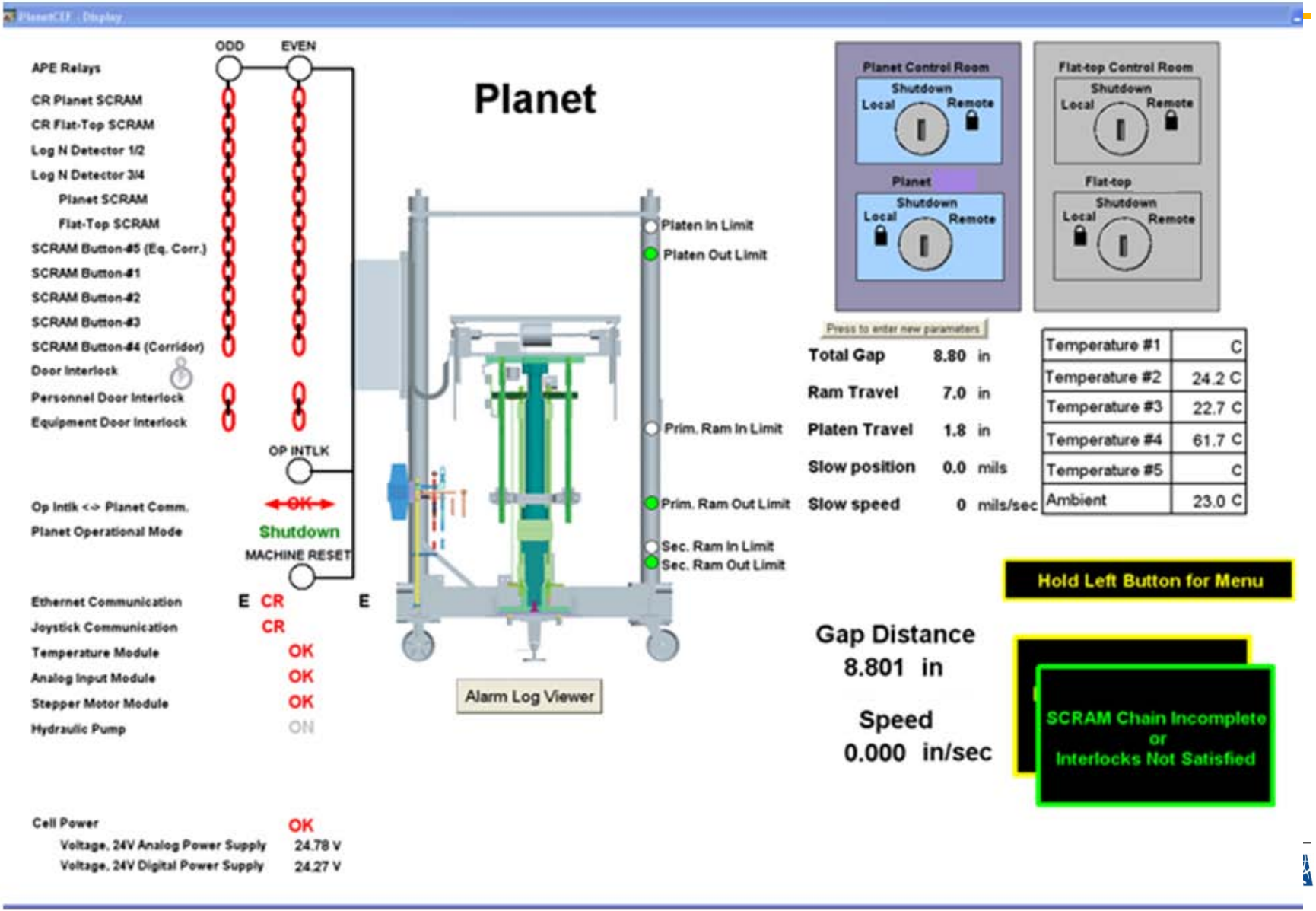
Can add up to 2 additional foils for a total of 10.

Will eventually reach a point where the next unit will either exceed the 1/2 way or 3/4 rule.

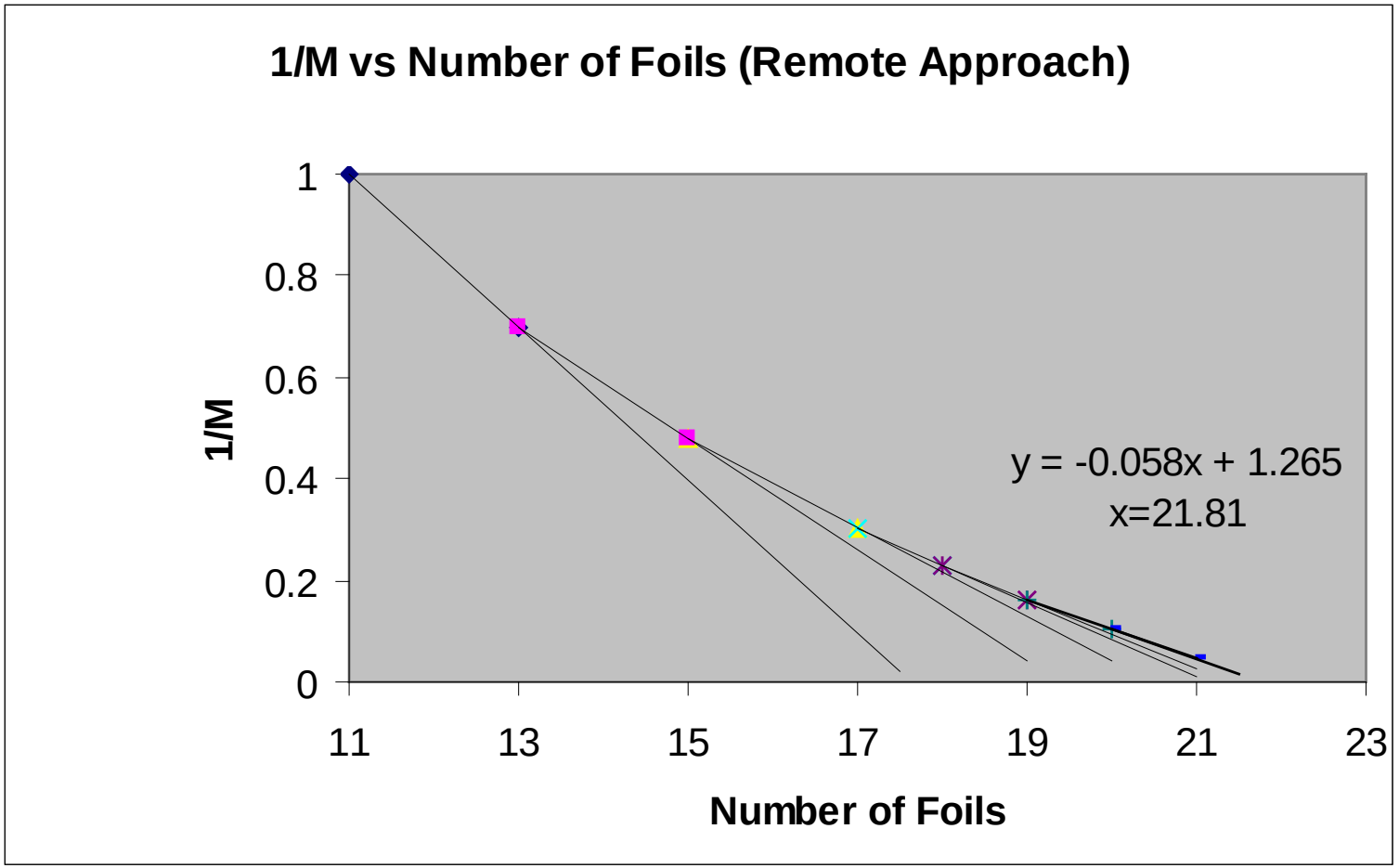
Handstacking stops

Planet

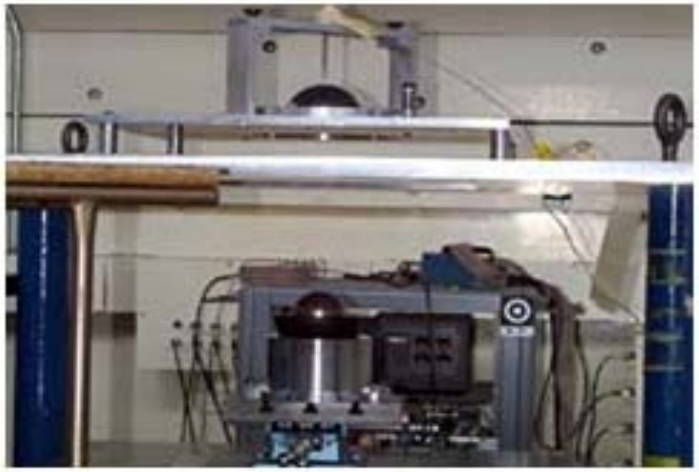
Planet


Planet
ODD
EVEN
APE Relays
CR Planet SCRAM
CR Flat-Top SCRAM
Log N Detector 1/2
Log N Detector 3/4
Planet SCRAM
Flat-Top SCRAM
SCRAM Button-#5 (Eq. Corr.)
SCRAM Button-#1
SCRAM Button-#2
SCRAM Button-#3
SCRAM Button-#4 (Corridor)
Door Interlock
Personnel Door Interlock
Equipment Door Interlock
OP INTLK
Op Intlk <-> Planet Comm.
OK
Planet Operational Mode
Shutdown
MACHINE RESET
Ethernet Communication
E CR
E
Joystick Communication
CR
Temperature Module
OK
Analog Input Module
OK
Stepper Motor Module
OK
Hydraulic Pump
ON
Cell Power
OK
Voltage, 24V Analog Power Supply
24.78 V
Voltage, 24V Digital Power Supply
24.27 V
Platen In Limit
Platen Out Limit
Prim. Ram In Limit
Prim. Ram Out Limit
Sec. Ram In Limit
Sec. Ram Out Limit
Alarm Log Viewer
Planet Control Room
Shutdown
Local
Remote
Planet
Shutdown
Local
Remote
Flat-top Control Room
Shutdown
Local
Remote
Flat-top
Shutdown
Local
Remote
Press to enter new parameters
Total Gap 8.80 in
Ram Travel 7.0 in
Platen Travel 1.8 in
Slow position 0.0 mils
Slow speed 0 mils/sec
Temperature #1 C
Temperature #2 24.2 C
Temperature #3 22.7 C
Temperature #4 61.7 C
Temperature #5 C
Ambient 23.0 C
Hold Left Button for Menu
Gap Distance
8.801 in
Speed
0.000 in/sec
SCRAM Chain Incomplete
or
Interlocks Not Satisfied

Planet


1/M vs Number of Foils (Remote Approach)
1/M
1
0.8
0.6
0.4
0.2
0
11
13
15
17
19
21
23
Number of Foils
y = -0.058x + 1.265
x=21.81

Planet



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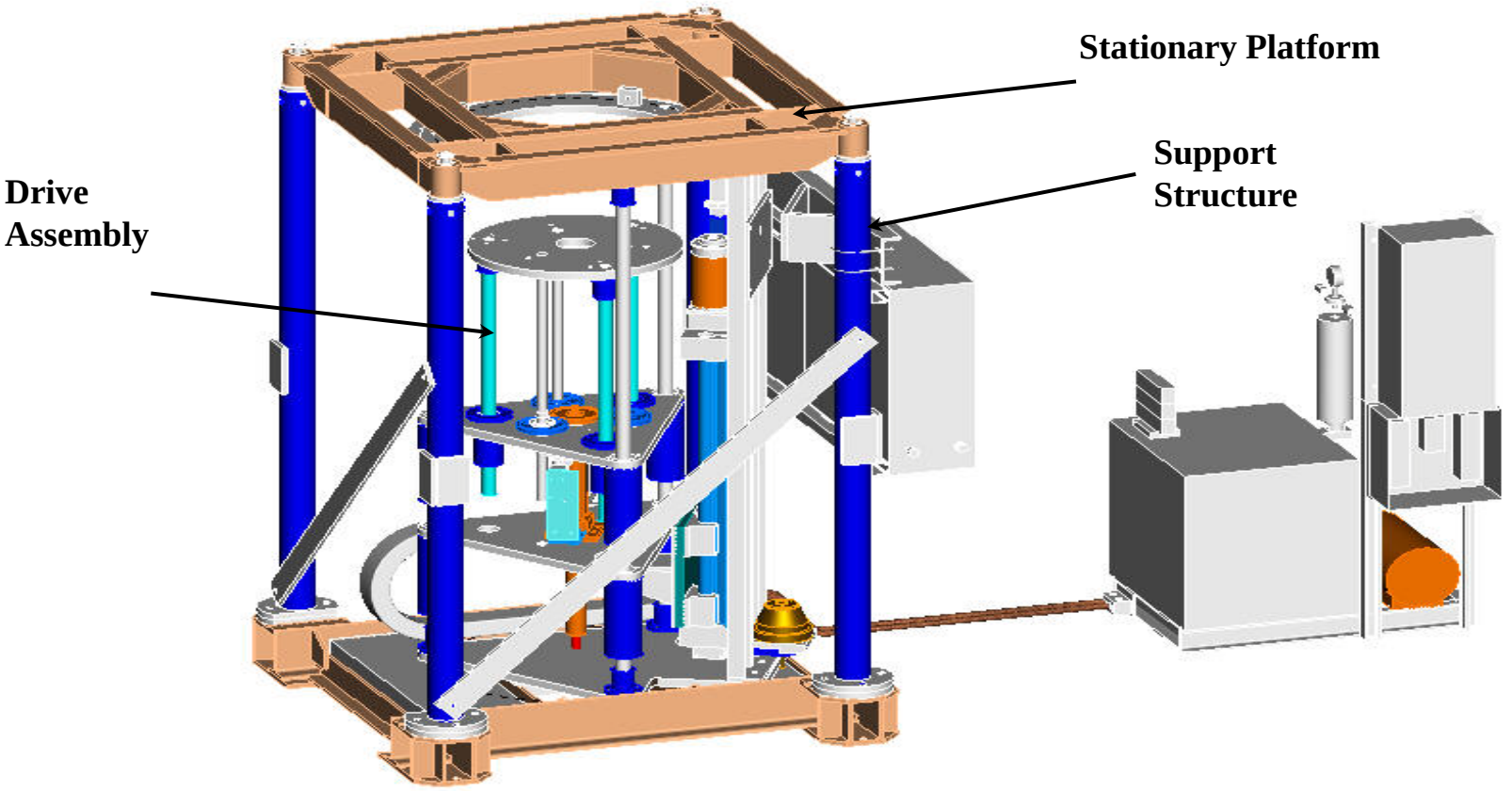
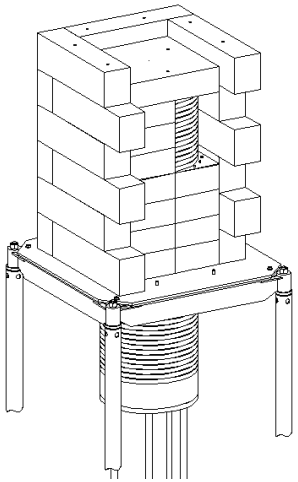
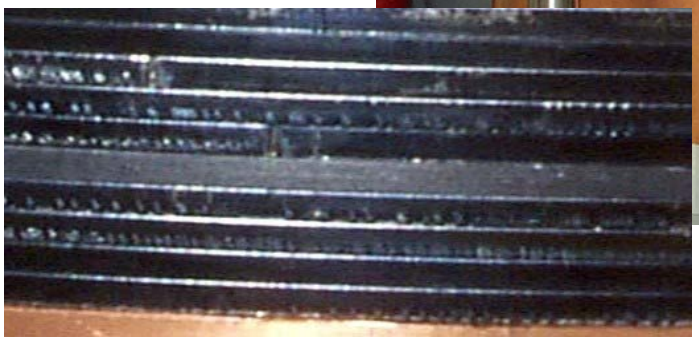
Comet



Comet

Zeus experiment on Comet





Comet

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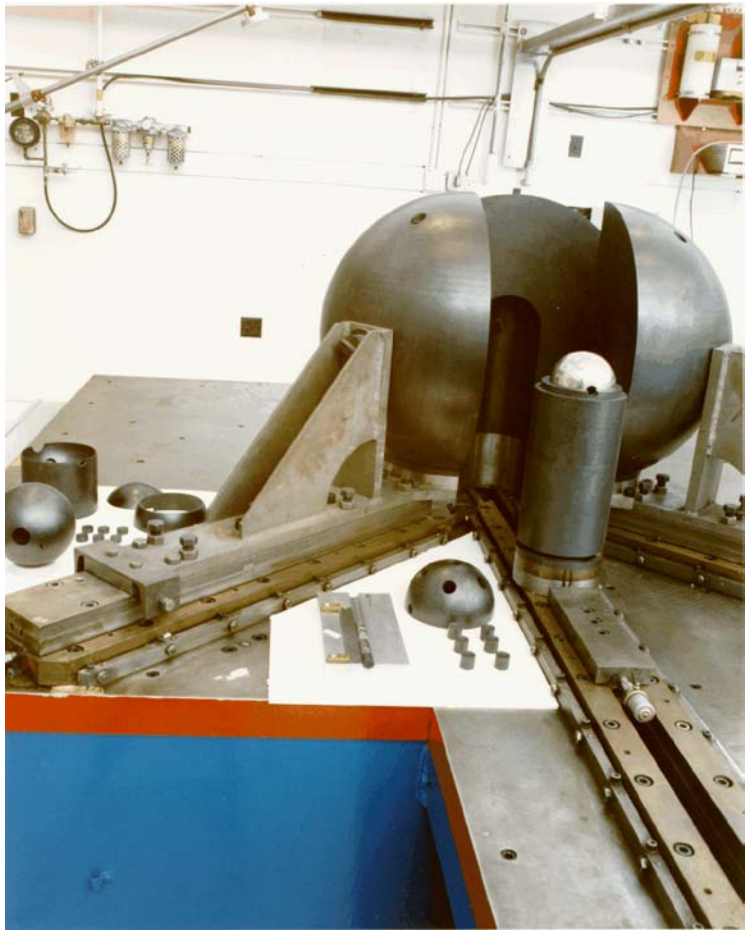
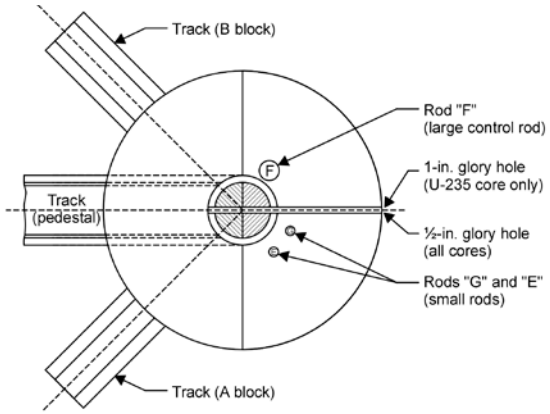
Flat-Top

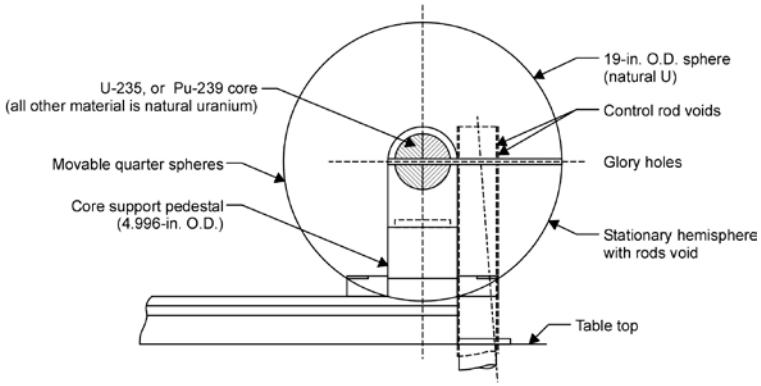


- Simple spherical geometry
- 1000 kg natural uranium reflector
  - 500 kg hemisphere
  - Two 250 kg quarter-sphere safety blocks
- U-235 and Pu-239 cores
- Can “free run” up to several kilowatts
  - Temperature increases of up to 300˚C
- Programs
  - Criticality safety training
  - Operator training

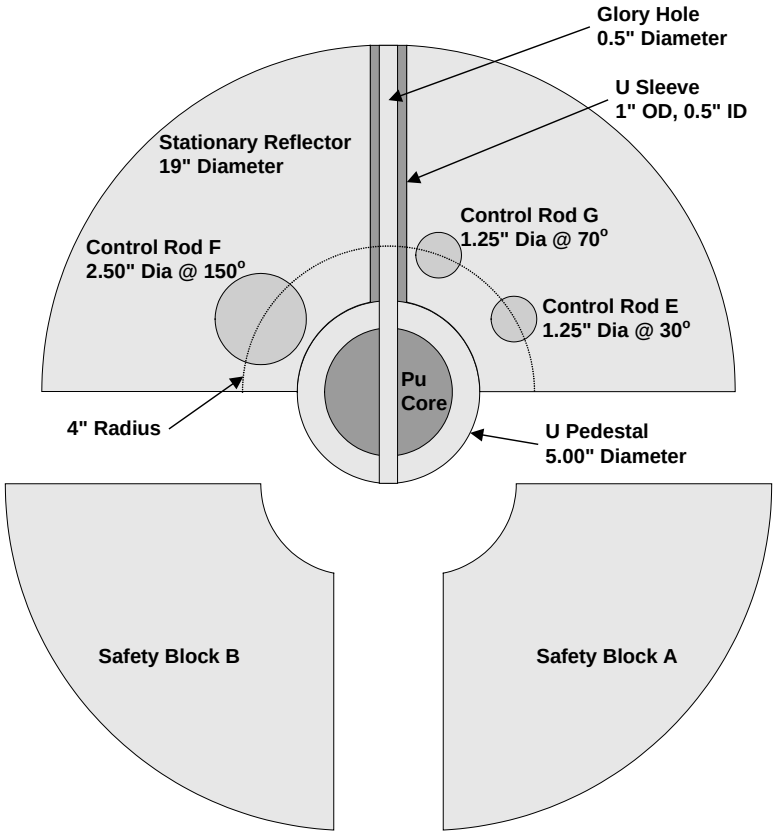
Flat-Top



Plan View

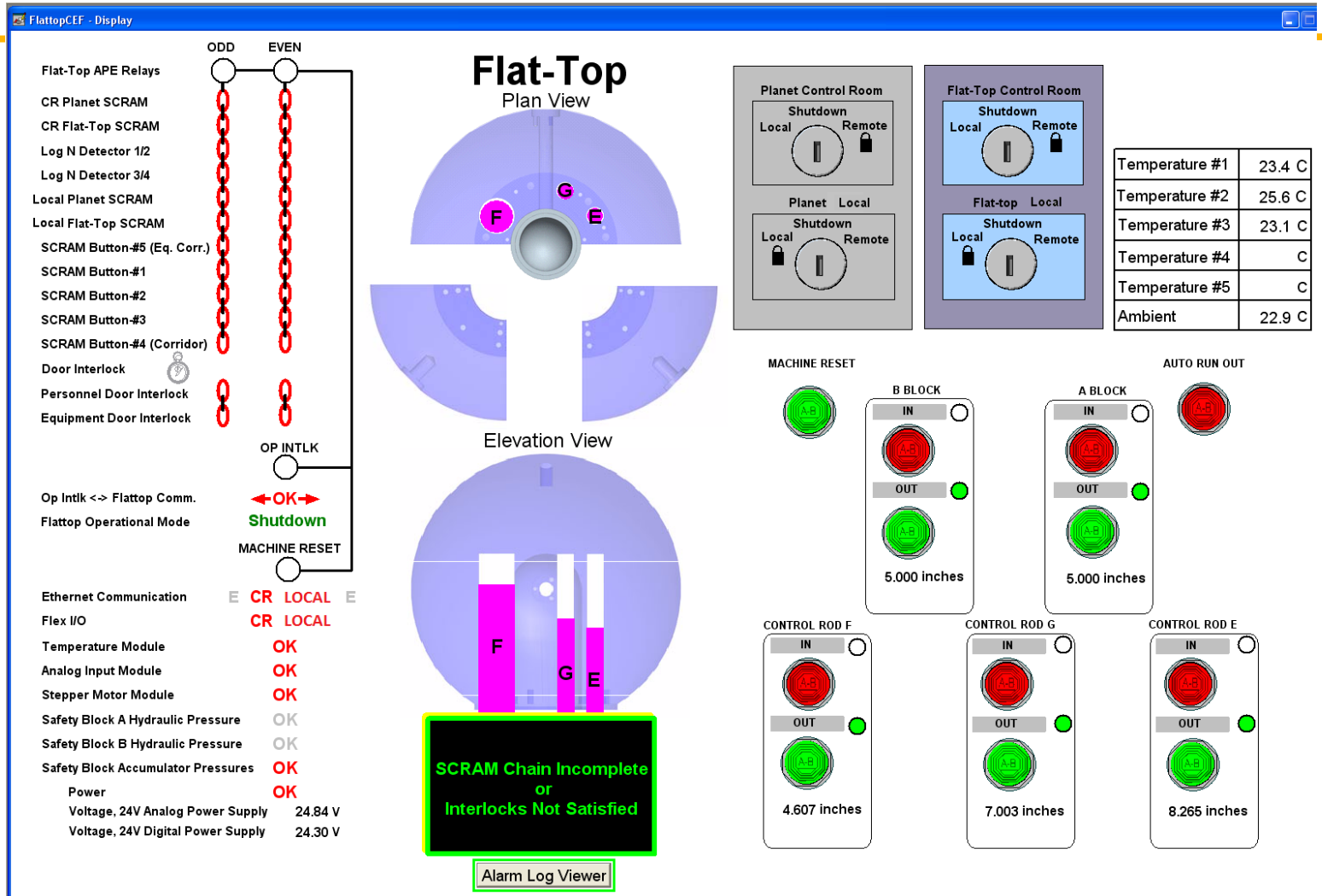


Elevation View



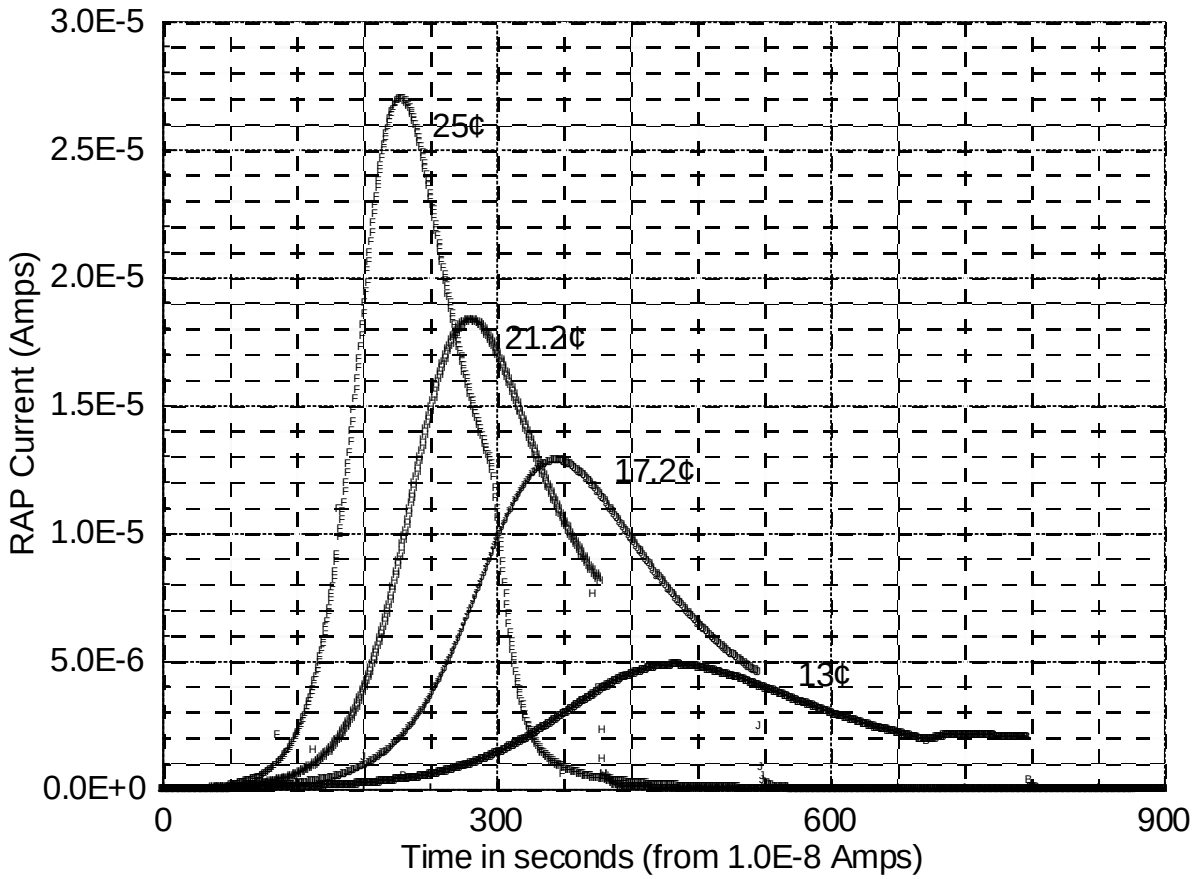
Pu Core: 3.57" Diameter
U Core: 4.77" Diameter
Rod Diameters are 13 mils less than the shown hole sizes

Flat-Top



Flat-Top

Free-Run Data (Oy)



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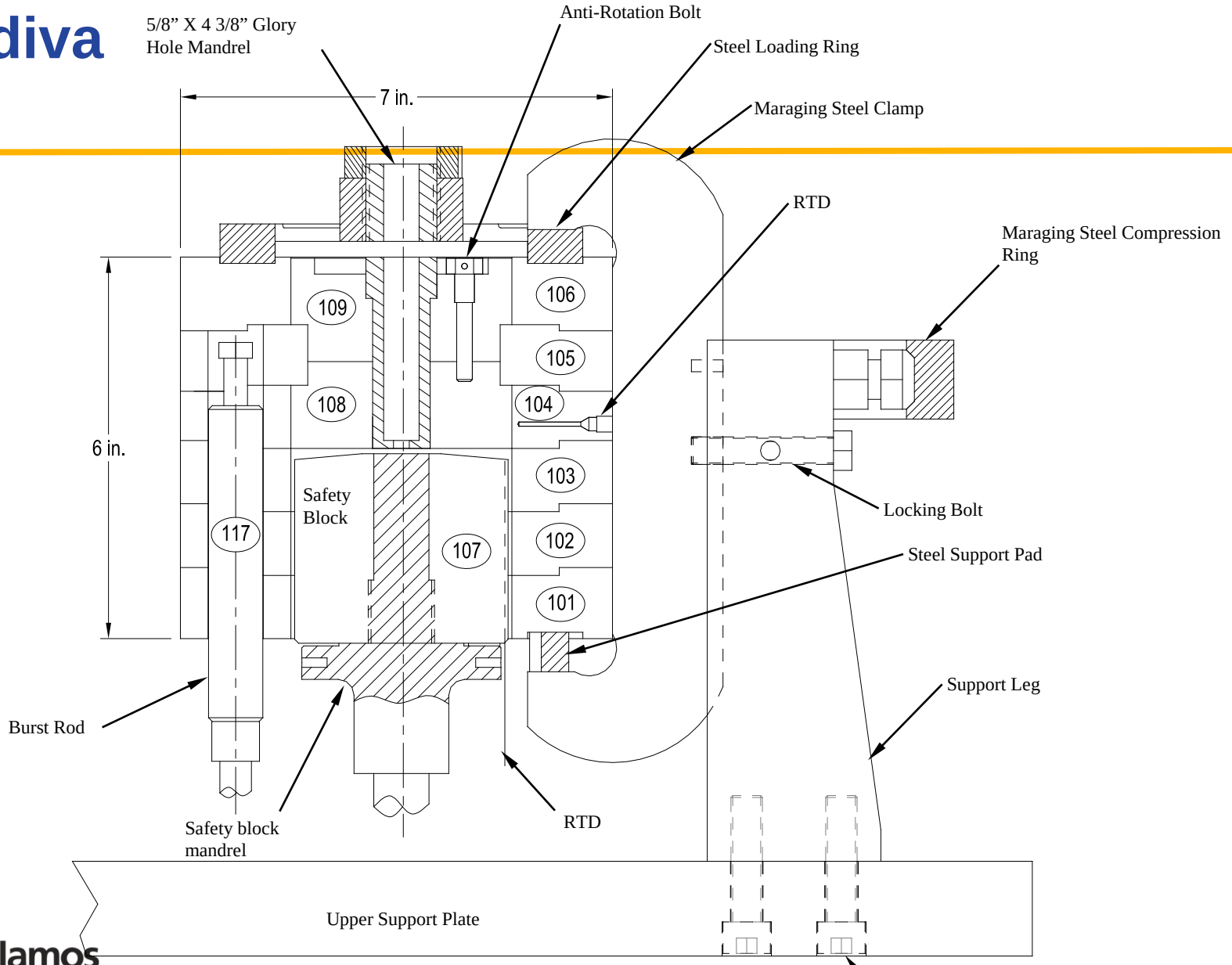
Godiva

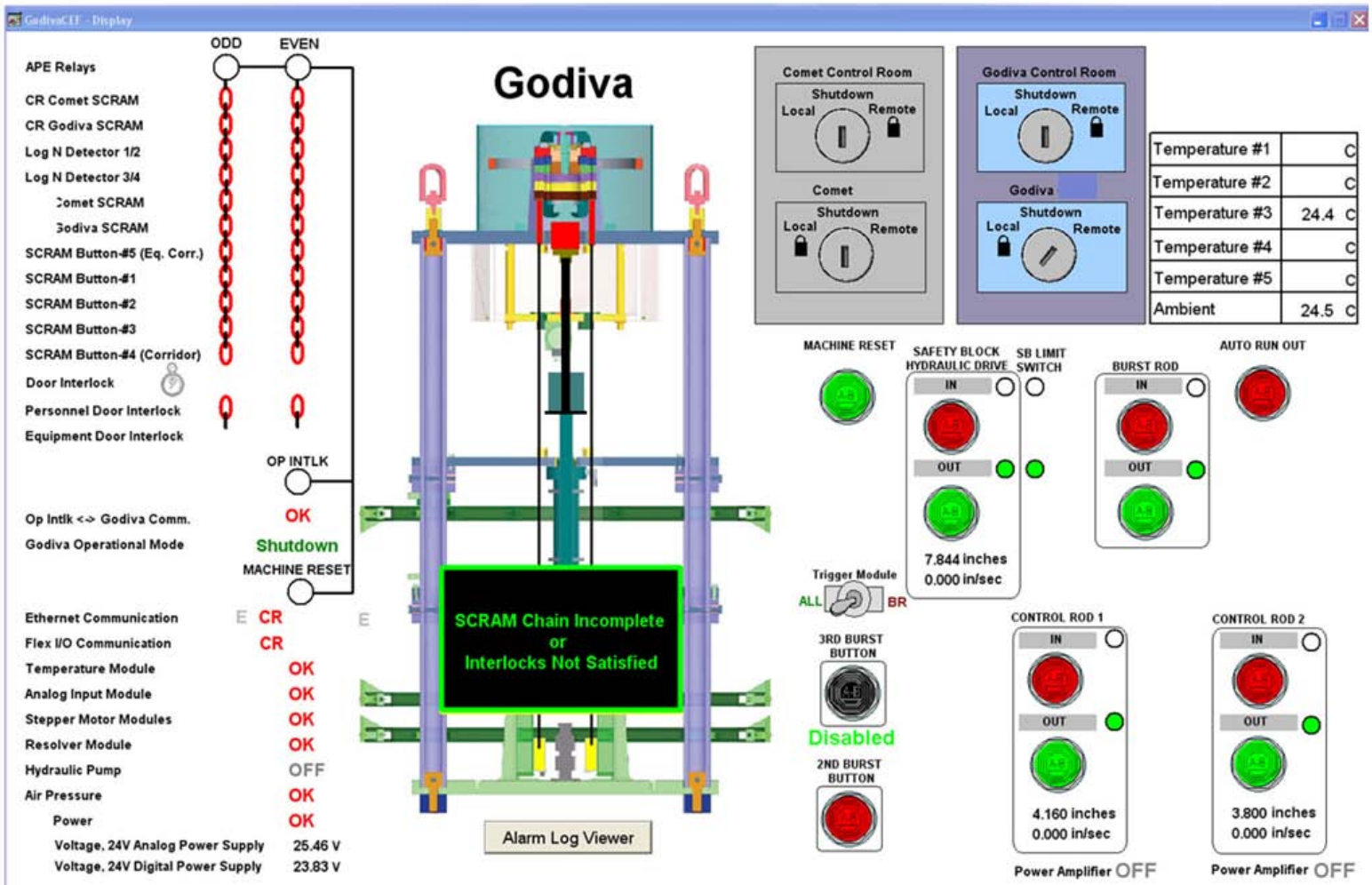
- Cylindrical uranium metal fast burst assembly
- 65 kg, 93% enriched
- 7-inch diameter (17.8 cm), 6-inch tall (15.2 cm)
- Operates at delayed critical or prompt critical

- Maximum burst is approximately 90,000 MW_{th} with a full width half max (FWHM) pulse of 25 μs

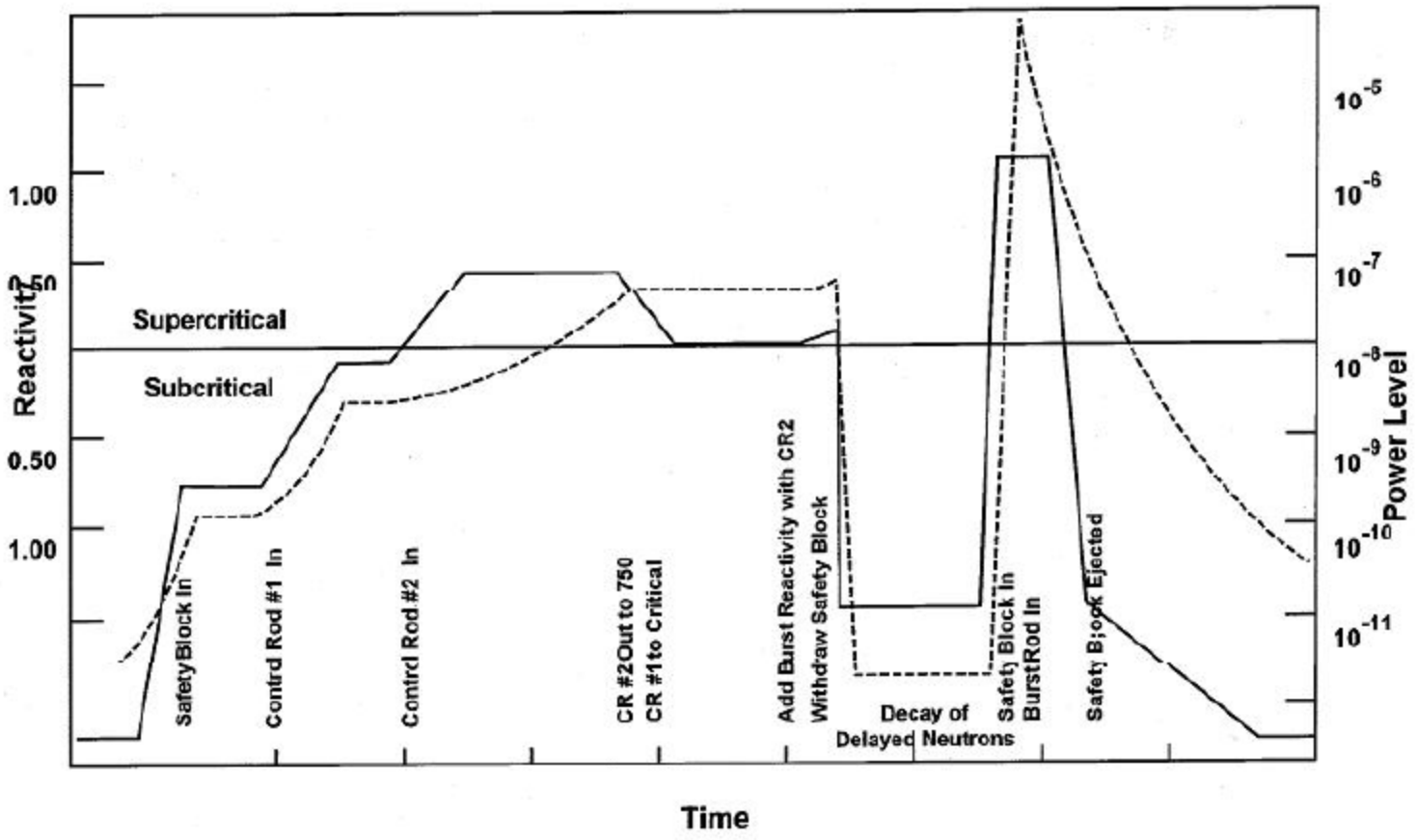
Godiva


5/8” X 4 3/8” Glory Hole Mandrel
Anti-Rotation Bolt
Steel Loading Ring
Maraging Steel Clamp
7 in.
RTD
Maraging Steel Compression Ring
6 in.
109
106
105
108
104
103
Safety Block
117
107
102
101
Locking Bolt
Steel Support Pad
Support Leg
Burst Rod
Safety block mandrel
RTD
Upper Support Plate
Attachment Bolts

Godiva


GodivaCLF - Display
Godiva
ODD
EVEN
APE Relays
CR Comet SCRAM
CR Godiva SCRAM
Log N Detector 1/2
Log N Detector 3/4
Comet SCRAM
Godiva SCRAM
SCRAM Button-#5 (Eq. Corr.)
SCRAM Button-#1
SCRAM Button-#2
SCRAM Button-#3
SCRAM Button-#4 (Corridor)
Door Interlock
Personnel Door Interlock
Equipment Door Interlock
OP INTLK
Op Intlk <-> Godiva Comm.
OK
Godiva Operational Mode
Shutdown
MACHINE RESET
Ethernet Communication
CR
Flex I/O Communication
CR
Temperature Module
OK
Analog Input Module
OK
Stepper Motor Modules
OK
Resolver Module
OK
Hydraulic Pump
OFF
Air Pressure
OK
Power
OK
Voltage, 24V Analog Power Supply
25.46 V
Voltage, 24V Digital Power Supply
23.83 V
SCRAM Chain Incomplete
or
Interlocks Not Satisfied
Alarm Log Viewer
Comet Control Room
Shutdown
Local
Remote
Comet
Shutdown
Local
Remote
Godiva Control Room
Shutdown
Local
Remote
Godiva
Shutdown
Local
Remote
Temperature #1
C
Temperature #2
C
Temperature #3
24.4 C
Temperature #4
C
Temperature #5
C
Ambient
24.5 C
MACHINE RESET
SAFETY BLOCK HYDRAULIC DRIVE
SB LIMIT SWITCH
IN
OUT
7.844 inches
0.000 in/sec
BURST ROD
IN
OUT
AUTO RUN OUT
Trigger Module
ALL
BR
3RD BURST BUTTON
Disabled
2ND BURST BUTTON
CONTROL ROD 1
IN
OUT
4.160 inches
0.000 in/sec
Power Amplifier OFF
CONTROL ROD 2
IN
OUT
3.800 inches
0.000 in/sec
Power Amplifier OFF

Godiva


Reactivity
1.00
0.50
1.00
Supercritical
Subcritical
Safety Block In
Contrd Rod #1 In
Contrd Rod #2 In
CR #2Out to 750
CR #1to Critical
Add Burst Reactivity with CR2
Withdraw Safety Block
Decay of
Delayed Neutrons
Safety Block In
BurstRod In
Safety Block Ejected
Time
Power Level
10-5
10-6
10-7
10-8
10-9
10-10
10-11

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Current status of critical assembly machines

- Comet, Planet, Flat-Top, and Godiva-IV have been installed at the National Criticality Experiment Research Center.

- All four machines received safety system upgrades along with new digital control systems.

- Between these machines, systems ranging from the thermal through the intermediate to the fast spectrum may be assembled. Steady-State, transient, and super-prompt critical conditions may be explored.

Current status of critical assembly machines

- Safety system upgrades:

- General
  - Two Independent, Redundant, PLC based SCRAM channels
  - Four Compensated Ion Chamber inputs (two per channel) with adjustable trip settings
  - Access Door Interlocks
  - Manual SCRAM Buttons
  - Modular “Plug and Play”

- Machine Specific
  - Upgraded hydraulics on Comet, Planet, and Flat-Top
  - Gravity withdrawal of Control Rods on Godiva-IV

Current status of critical assembly machines

- Planet IER-192 (CED-4a) Initial Critical 15JUN12
- Comet IER-193 (CED-4a) Initial Critical 11AUG12
- Godiva IER-194 (CED-3b) Assembled 24APR12
  Need to complete characterization
- Flat-Top IER-195 (CED-3b) Initial Critical on Uranium Core 30NOV12

Current status of critical assembly machines

•Future work includes:

- Hands-On Nuclear Criticality Safety Training
- Intermediate energy spectrum experiments
- Criticality properties of actinides
- Dosimetry studies
- Accident analysis benchmarks
- Reaction rate and fission-product yield measurements
- Experimental error reduction and reproducibility measurements
- Benchmark critical configurations with structural material diluents

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Nuclear Material Items

- We have a large quantity of nuclear material at DAF.
  - Uranium, plutonium, and neptunium
- Multiple pieces of nuclear material with reflector materials (polyethylene, steel, depleted uranium, etc.) may be constructed.
  - Criticality safety documents describe activities that are authorized
- Nuclear material handling and measurement applications include:
  - Neutron and gamma diagnostic measurements
  - Benchmark measurements
  - Validation of instruments, analysis methods, algorithms, and simulation capabilities
  - Hands-on training

Nuclear Material Items

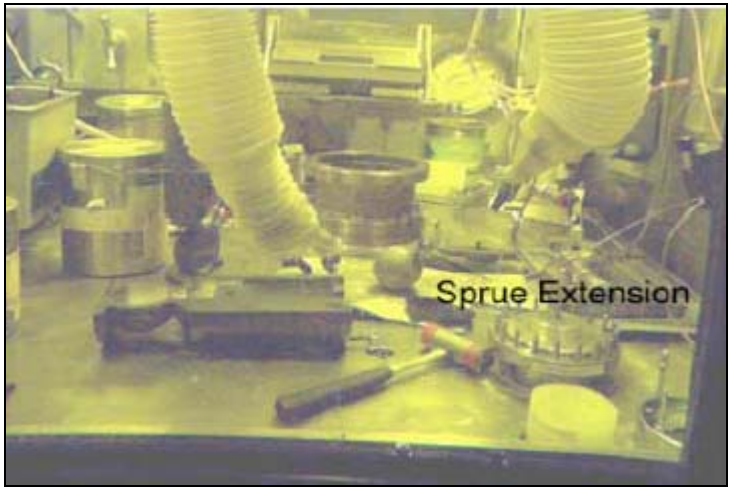
- Beryllium Reflected Plutonium Ball (BeRP Ball)
- 4.5 kg α-phase Pu (94 wt.% 239)
- Allowed reflector materials include: polyethylene, acrylic, lead, borated poly, iron, nickel, and tungsten.

Nuclear Material Items

- Rocky Flats shells.
- HEU hemishells that are about 1/8 inch thick.

Nuclear Material Items

- 6 kg sphere of Np-237
- Allowed reflector materials include: polyethylene, borated polyethylene, NU, DU, lead, and iron.



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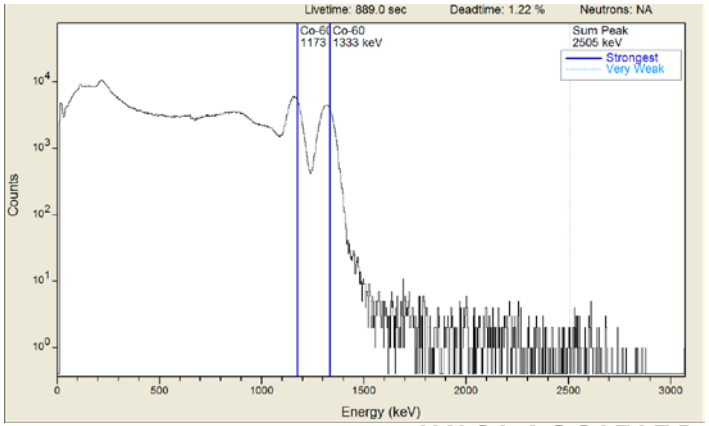
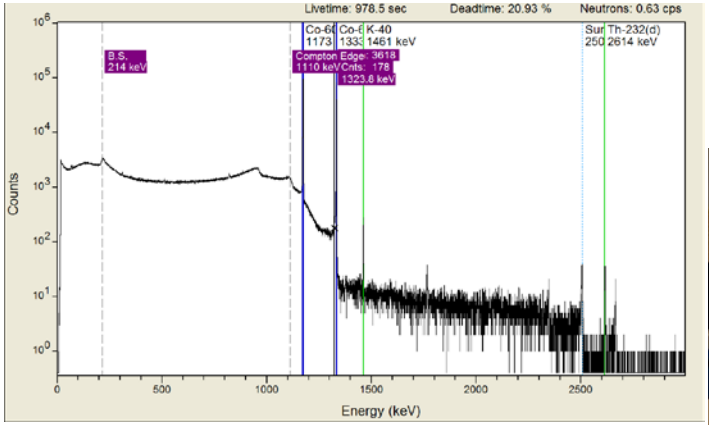
Radiation detector measurements

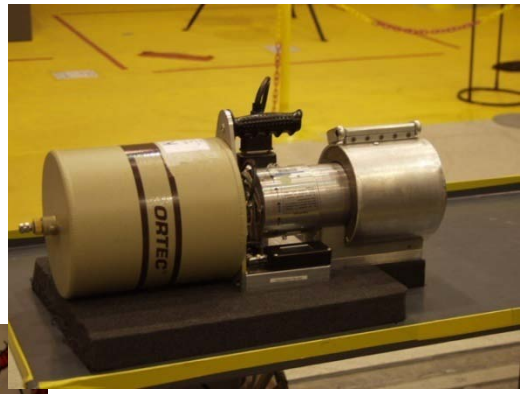
- Measurement activities general consist of:
  1. Search instruments: gamma and/or neutron instruments that are light (either in handheld or backpack form).
     - Can be used to measure/estimate: dose rates, isotope identification, hotspot determination.
     - Generally consist of NaI, LaBr, CsI, or CZT detectors for gamma identification, He-3 for neutron count rates, and/or a Geiger-Mueller tube for dose rate information.



Radiation detector measurements

- Measurement activities general consist of:
  2. High Fidelity Gamma detectors:
     - Can be used for isotope identification and mass quantification.
     - Resolution and efficiency are much better than for the search instruments.
     - Generally consist of HPGe





Radiation detector measurements

- Measurement activities general consist of:
  3. High Fidelity Neutron detectors:
     - Can be used to estimate the multiplication and mass of nuclear material or to estimate the neutron source strength of sources/nuclear material.
     - Generally consist of polyethylene-moderated He-3 tubes.

Submit an Experiment Request!

U. S. Department of Energy
Nuclear Criticality Safety Program

http://ncsp.llnl.gov/